INDOOR AIR QUALITY ASSESSMENT

Berkley Town Offices
1 North Main Street
Berkley, Massachusetts

Prepared by:
Massachusetts Department of Public Health
Center of Environmental Health
Emergency Response/Indoor Air Quality Program

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Background/Introduction

At the request of Joseph Senato, Selectman, the Massachusetts Department of Public Health (MDPH), Center of Environmental Health (CEH) provided assistance and consultation regarding indoor air quality at the Berkley Town Office Building (BTOB), 1 North Main Street, Berkley, Massachusetts. Concerns about water damage and mold prompted the request. On November 9, 2005, a visit was made to this building by Michael Feeney, Director of Emergency Response/Indoor Air Quality (ER/IAQ), CEH, to conduct an indoor air quality assessment.

The BTOB is a one-story, brick structure originally constructed as a school in the 1930s. The building was renovated with the installation of restrooms in the 1970s. The first floor currently has town offices. The basement contains offices, the town museum and storage areas. Windows are openable throughout the first floor of the building and appear to be retrofitted with energy efficient frames and sashes.

Methods

Air tests for carbon dioxide, temperature and relative humidity were taken with the TSI, Q-Trak, IAQ Monitor Model 8551. Water content of building materials was measured using a Delmhorst, BD-2000 Model, Moisture Detector with a Delmhorst Standard Probe. Moisture measurements were taken in carpeting and wood. Tests were taken during normal operations.

Results

The BTOB has an employee population of 8 and is visited by up to 30 people daily. Tests were taken during normal operations and results appear in Table 1.

Discussion

Ventilation

It can be seen from the Table 1 that carbon dioxide levels were below 800 parts per million (ppm) of air in all areas surveyed, indicating adequate air exchange. However it should be noted that none of the building's mechanical or natural (e.g., gravity) ventilation systems were operational at the time of the assessment.

Fresh air ventilation was originally provided by unit ventilators (univents). Univents draw fresh air from a vent on the exterior of the building and air from the room (called return air) through a vent in the base of the unit (Figure 1). Fresh air and return air are mixed, filtered, heated and provided to rooms through a fresh air diffuser located in the top of the unit. Please note that fresh air intakes for univents were sealed with plywood (Picture 1). With the sealing of the fresh air intakes, the sole source of fresh air is through openable windows.

Exhaust ventilation is drawn into ungrated holes located at floor level (Picture 2) and vents located inside of spaces originally designed as coat closets (Picture 3). No airflow was detected from any of the exhaust vents examined. Building staff did report that closet doors would rattle during weather with high wind, which would indicate that this system is a non-mechanical, "gravity" system. A louver located inside the duct controls airflow. Above the louver is usually a heating element that creates airflow via rising heat called “the stack effect”. Under these circumstances, it appears that the building does not have a functioning exhaust ventilation system. Without exhaust ventilation, normally occurring environmental pollutants can build up and lead to air quality/comfort complaints.

During summer months, ventilation was supplemented by the use of openable windows. The building was configured in a manner to use cross-ventilation to provide comfort for building occupants. The BTOB is equipped with windows on opposing exterior walls. This design allows for air to enter an open window, pass through a room, pass through the open door, enter the hallway, pass through the opposing room’s open door, into the opposing room and exit the building on the leeward side (opposite the windward side) (Figure 2). With all windows and hallway doors open, airflow can be maintained in a building regardless of the direction of the wind. The system fails if the windows or doors are closed (Figure 3). In addition, open windows may also allow for rainwater to penetrate through windows. Pests such as bats and insects also have access to the interior if windows are left open overnight.

To maximize air exchange, the MDPH recommends that both supply and exhaust ventilation operate continuously during periods of school occupancy. In order to have proper ventilation with a mechanical supply and exhaust system, the systems must be balanced to provide an adequate amount of fresh air to the interior of a room while removing stale air from the room. The date of the last servicing and balancing was not available at the time of the assessment. It is recommended that existing ventilation systems be re-balanced every five years to ensure adequate air systems function

(SMACNA, 1994). Please note that the ventilation systems cannot be balanced in their current condition.

The Massachusetts Building Code requires a minimum ventilation rate of 15 cubic feet per minute (cfm) per occupant of fresh outside air or have openable windows in each room (SBBRS, 1997; BOCA, 1993). The ventilation must be on at all times that the room is occupied. Providing adequate fresh air ventilation with open windows and maintaining the temperature in the comfort range during the cold weather season is impractical. Mechanical ventilation is usually required to provide adequate fresh air ventilation.

Carbon dioxide is not a problem in and of itself. It is used as an indicator of the adequacy of the fresh air ventilation. As carbon dioxide levels rise, it indicates that the ventilating system is malfunctioning or the design occupancy of the room is being exceeded. When this happens a buildup of common indoor air pollutants can occur, leading to discomfort or health complaints. The Occupational Safety and Health Administration (OSHA) standard for carbon dioxide is 5,000 parts per million parts of air (ppm). Workers may be exposed to this level for 40 hours/week, based on a time-weighted average (OSHA, 1997).

The Department of Public Health uses a guideline of 800 ppm for publicly occupied buildings. A guideline of 600 ppm or less is preferred in schools due to the fact that the majority of occupants are young and considered to be a more sensitive population in the evaluation of environmental health status. Inadequate ventilation and/or elevated temperatures are major causes of complaints such as respiratory, eye, nose and throat irritation, lethargy and headaches. For more information concerning carbon dioxide, please see Appendix A.

Temperature readings ranged from 68^{o} F to 76 ^{o} F in occupied areas, which were slightly below the MDPH recommended comfort guidelines in several areas. The MDPH recommends that indoor air temperatures be maintained in a range of 70 ^{o} F to 78 ^{o} F in order to provide for the comfort of building occupants. In many cases concerning indoor air quality, fluctuations of temperature in occupied spaces are typically experienced, even in a building with an adequate fresh air supply. Temperature control is difficult in an old building without a functioning ventilation system.

The relative humidity ranged from 39 to 44 percent in occupied areas, which was below the MDPH recommended comfort range. The MDPH recommends a comfort range of 40 to 60 percent for indoor air relative humidity. It is important to note however, that relative humidity measured in the basement storerooms was 8 to 10 percent higher than any areas on the first floor. This increase in relative humidity can indicate moisture sources that exist within the basement storerooms. Moisture removal is important since the sensation of heat increases as relative humidity increases (the relationship between temperature and relative humidity is called the heat index). Please note relative humidity in the building would be expected to drop during the winter months due to heating. The sensation of dryness and irritation is common in a low relative humidity environment. Low relative humidity is a common problem during the heating season in the northeast part of the United States.

Microbial/Moisture Concerns

During the fall of 2005, New England experienced a stretch of heavy rainfall and flooding in September and October. As an example, the general Berkley vicinity had approximately 3.5 inches of rain on September 15 and 16, 2005, as well as 6.7 inches of rain on October 14 and 15, 2005 (The Weather Underground, 2005). Pictures taken by Phyllis Brennan, Berkley Board of Assessors, on September 15, 2005, depict substantial water penetration through windows, wet carpeting, water damage to stored materials and water pooling on the basement floor (Pictures 4 through 9).

Water damage and mold colonization of stored materials and building components were found in every accessible location in the basement. Materials such as cardboard boxes (Pictures 7 and 8), paneling (Picture 9), gypsum wallboard (Picture 10), ceiling plaster and ceiling tiles (Pictures 11 and 12), and wood (Picture 13) all had visible mold colonies. Other stored materials also showed signs of mold colonization or water damage (Pictures 14 through 18).

In an effort to ascertain moisture content of flooring materials in the building, samples were taken in carpeting on the first floor (Table 1). A Delmhorst probe was inserted into carpet or into seams of plywood flooring. The Delmhorst probe is set to sound a signal when a moisture reading of $\geq$ 15 in wood is detected. The the wood floor and carpet in the room 2 was saturated several feet from the window (Picture 19) on the day of the assessment.

The US Environmental Protection Agency (EPA) and the American Conference of Governmental Industrial Hygienists (ACGIH) recommends that porous materials be dried with fans and heating within 24 to 48 hours of becoming wet (US EPA, 2001; ACGIH, 1989). If porous materials are not dried within this time frame, mold growth may occur. Once mold growth has occurred, disinfection of these materials may be possible. Since GW, wood and carpeting are porous surfaces; disinfection is likely to be ineffective. Removal of these materials is likely needed to prevent exposure to mold and other associated pollutants.

The BTOB appears to have a number of breaches/conditions through the building envelope that allows water to penetrate into the building. The following is a list of likely building envelope breaches.

- A section of wall above the front windows of the selectmen's office and south door are notably bulging outward (Pictures 20 and 21). The south door was ordered to be locked and blocked off by the Berkley Inspector of Buildings (Appendix B).
- Numerous areas of missing/failing mortar between exterior wall bricks were noted (Picture 22). In some cases, spray foam insulation was applied to these spaces (Pictures 23 and 24) which would hold water inside the exterior wall cavity. (Spray foam insulation is a water impermeable material that would dam water behind brick and mortar. Brick and mortar are porous materials through which water may pass.)
- A large breach exists in the rear exterior wall of the building (Picture 25). During renovations of the BTOB, building occupants indicated that the building originally had a rear entrance that was sealed to create restrooms. The opening for the former door appeared to be only covered with tar paper. In the experience of CEH staff, an aperture in the building envelope is usually sealed with a like material to that of the building envelope, in this case brick and mortar.

- Areas of the roof are missing flashing (Picture 26).
- Downspouts appear to be clogged, as evidenced by moss and water staining on the exterior wall behind the pipe joints (Picture 27).
- Condensation on the inside of energy efficient windows indicates that the gaskets have failed, allowing moisture penetration (Picture 28).
- Air conditioners were installed in a manner that allows driving rainwater to penetrate, wetting window sills and carpeting (Picture 4).
- A basement entrance exists at the rear of the building (Picture 29). The door is water damaged and the floor of the threshold is covered with accumulated leaves, which would block drainage, if one exists.

In order to explain how mold and associated odors/particulates in the basement can migrate into occupied areas, the following concepts must be understood:

- Heated air (from radiators) will create upward air movement (called the stack effect).
- Cold air moves to hot air, which creates drafts.
- As the heated air rises, negative pressure is created, which draws cold air to the heat source.
- Airflow created by the stack effect, drafts or mechanical ventilation can draw airborne particulates into the air stream (i.e. from the basement).
- The opening of the door to the basement at the base to the main stairwell can provide a pathway for air to travel from the basement to the upper floors.

Each of these concepts has an influence on the movement of basement odors or other particulates into occupied areas. In order to control possible mold growth, water penetration into the basement area must be minimized.

Conclusions/Recommendations

The conditions found within the building raise a number of indoor air quality issues. Rainwater penetration has caused damage to the building on the first floor and basement. It appears that water penetration is a chronic problem that persistently moistens building materials, such as GW, wood and carpeting. All means to mechanically vent the building were inoperable. Without a mechanical ventilation system environmental pollutants are neither diluted nor removed from the BTOB. This can result in a buildup of airborne dust, moisture and other pollutants in the indoor environment. At this point, individuals who have a hypersensitivity to mold should avoid entering the basement.

The creation of an unconditioned space in the basement without the means to control temperature or relative humidity have created conditions that subjected stored materials (e.g., book collections and museum artifacts) to mold colonization. A decision should be made concerning the mold contaminated materials stored in this area. These books, boxes, documents and other materials will continue to be a source of mold associated particulates/odors, unless the items are removed/remediated. As an initial step, options concerning the preservation of materials stored in this area should be considered. Porous materials that are judged not worthy of preservation, restoration or transfer to another media (e.g., microfiche or computer scanning) should be discarded. Where stored materials are to be preserved, restored or otherwise handled, an evaluation should be conducted by a professional book/records conservator. This process can be expensive, and may be considered for conservation of irreplaceable documents that are colonized with mold.

Removing water damaged materials from the building in an appropriate manner will most likely addresses issues of immediate concern. However, the condition of the building envelope most likely will result in repeated water damage to materials stored in the basement. At this time, we believe that a building engineer would be the most appropriate individual to examine the building.

To remedy building problems, a two-phase approach is recommended consisting of immediate (**short-term**) measures to remove mold-colonized materials and remediate water damaged sections of the building and **long-term** measures that will require planning and resources to adequately address the overall indoor air quality concerns.

Short Term Recommendations

1. Keep the stairwell door to the basement closed.
2. Consider relocating personnel in the basement to other (non-affected) areas of the building.
3. Remove and replace any mold contaminated/water damaged building materials (GW, carpet, ceiling tiles, etc.). This measure will remove actively growing mold colonies that may be present. Remove mold contaminated materials in a manner consistent with recommendations found in "Mold Remediation in Schools and Commercial Buildings" published by the US Environmental Protection Agency (US EPA, 2001). The document is available at the US EPA website: http://www.epa.gov/iaq/molds/mold_remediation.html. Removing water-damaged GW and wooden trim will also provide maintenance personnel with the opportunity to observe

conditions within the wall cavity and determine whether any signs of water penetration through breaches of the building envelope exist.

4. Remove leaves from basement entrance shown in Picture 29 to determine if drain is present, if so; ensure that the drain works appropriately.
5. Reinstall window-mounted air conditioners in a manner to prevent water penetration and drafts.
6. Make repairs to gutter/downspout system to drain water away from the building.
7. Replace water damaged door to the basement rear entrance.
8. Use openable windows to provide air exchange. Care should be taken to ensure windows are properly closed at night and weekends to avoid the freezing of pipes and potential flooding.
9. For buildings in New England, periods of low relative humidity during the winter are often unavoidable. Therefore, scrupulous cleaning practices should be adopted to minimize common indoor air contaminants whose irritant effects can be enhanced when the relative humidity is low. To control for dusts, a high efficiency particulate arrestance (HEPA) filter equipped vacuum cleaner in conjunction with wet wiping of all surfaces is recommended. Avoid the use of feather dusters. Drinking water during the day can help ease some symptoms associated with a dry environment (throat and sinus irritations).

Long Term Recommendations

The key to addressing on-going water penetration and indoor air quality problems in the building is to re-establish the integrity of the building envelope and restore mechanical ventilation. These remedial efforts can include the following activities:

1. Consult with a structural engineer to evaluate the structural integrity of the building.
2. Repair roof flashing. Have structural engineer determine if the building's support system can hold the weight of a new roof.
3. Re-point the exterior brickwork where water damage is evident.
4. Replace and/or restore the window system in the building.
5. Repair of water-damaged plaster once the building envelope is reestablished.
6. Contact an HVAC engineering firm for an assessment of the ventilation system's control system (e.g., controls, air intake louvers, thermostats). Based on the age, physical deterioration and availability of parts for ventilation components, such an evaluation is necessary to determine the operability and feasibility of repairing/replacing the equipment.

References

ACGIH. 1989. Guidelines for the Assessment of Bioaerosols in the Indoor Environment. American Conference of Governmental Industrial Hygienists, Cincinnati, OH.

BOCA. 1993. The BOCA National Mechanical Code-1993. 8th ed. Building Officials & Code Administrators International, Inc., Country Club Hills, IL. M-308.1

OSHA. 1997. Limits for Air Contaminants. Occupational Safety and Health Administration. Code of Federal Regulations. 29 C.F.R. 1910.1000 Table Z-1-A.

SBBRS. 1997. Mechanical Ventilation. State Board of Building Regulations and Standards. Code of Massachusetts Regulations. 780 CMR 1209.

SMACNA. 1994. HVAC Systems Commissioning Manual. 1st ed. Sheet Metal and Air Conditioning Contractors' National Association, Inc., Chantilly, VA.

US EPA. 2001. Mold Remediation in Schools and Commercial Buildings. US Environmental Protection Agency, Office of Air and Radiation, Indoor Environments Division, Washington, D.C. EPA 402-K-01-001. March 2001. http://www.epa.gov/iaq/molds/mold_remediation.html

The Weather Underground. 2005. Weather History for Fall River, Massachusetts, September-October, 2005. http://www.wunderground.com/history

Picture 1

Sealed Fresh Air Intake

Picture 2

Exhaust Vent, First Floor

Picture 3

Exhaust Vent Closet

Picture 4

Water Penetrating Into Building under Window-Mounted Air Conditioner
(Photo By Phyllis Brennan, Berkley Board of Assessors, 9/15/2005)

Picture 5

Records Room Entrance (Room 8)
(Photo By Phyllis Brennan, Berkley Board of Assessors, 9/15/2005)

Picture 6

Water Damaged Carpet, Room 2
(Photo By Phyllis Brennan, Berkley Board of Assessors, 9/15/2005)

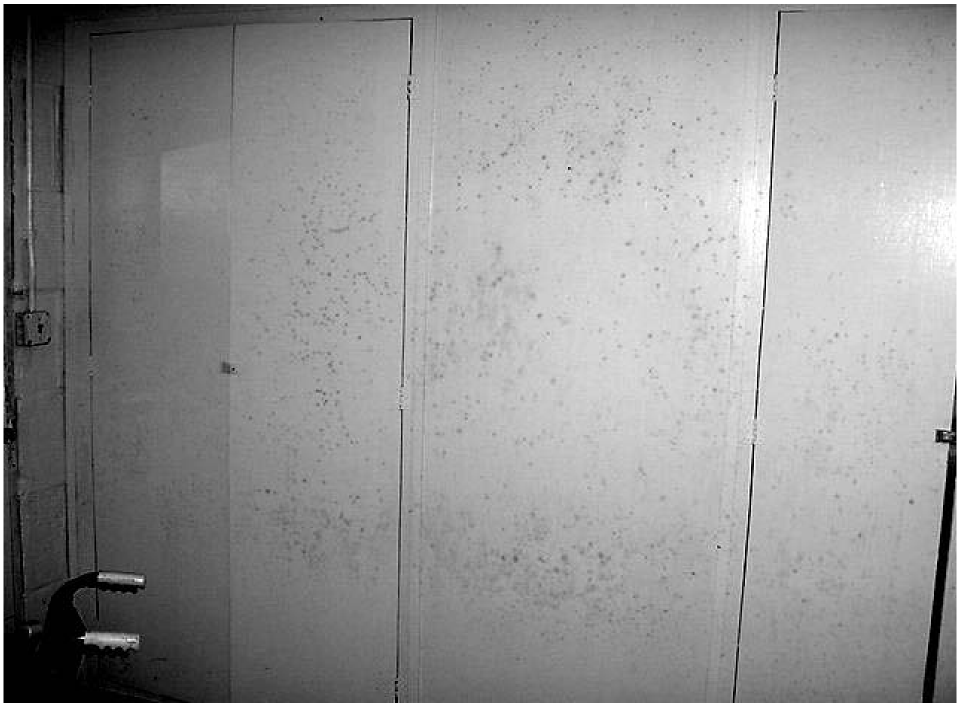
Picture 7

Flooded Room 8
(Photo By Phyllis Brennan, Berkley Board of Assessors, 9/15/2005)

Picture 8

Mold Colonized Boxes, Room 8 (Compare To Picture 7)

Picture 9



Mold Colonized Paneling

Picture 10

Water Damaged Gypsum Wallboard, Basement

Picture 11

Mold Colonized Ceiling Plaster, Basement

Picture 12

Water Damaged Ceiling Tiles

Picture 13

Mold Colonized Door, Basement

Picture 14

Mold Colonized Wheel Chair, Basement

Picture 15

Mold Colonized Chair Basement

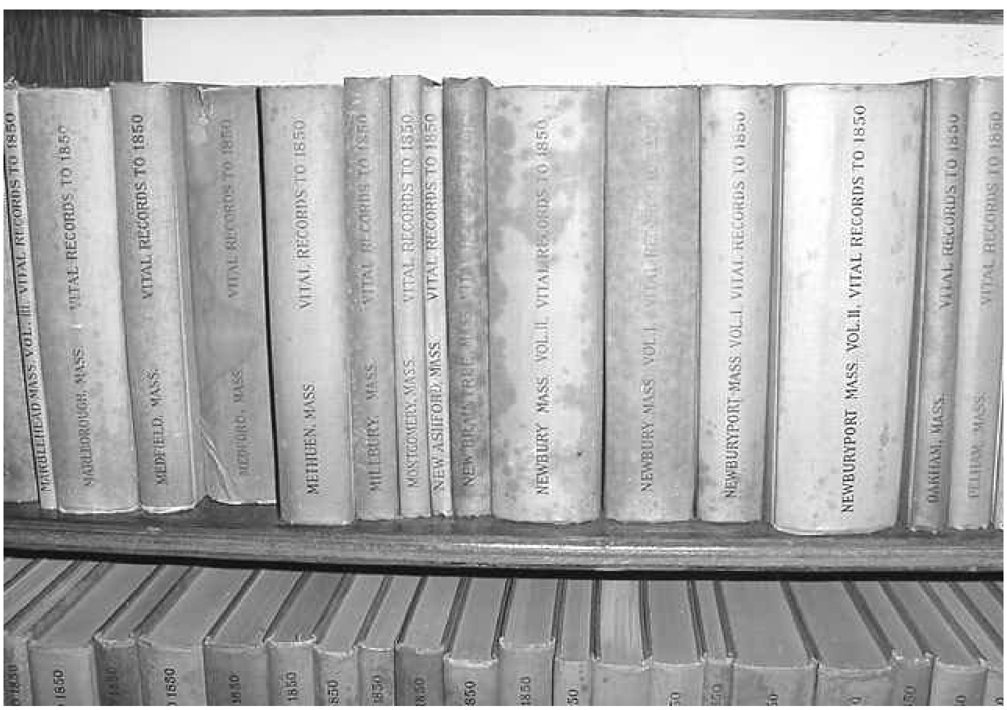
Picture 16

Mold Colonized Chair, Basement

Picture 17

Mold Colonized Instrument Case in Museum, Basement

Picture 18



Mold Colonized Books in Museum, Basement

Picture 19

Water Saturated Carpet in Room 2
(Ruler on Floor Indicates Edge of Carpet Saturation from Exterior Wall)

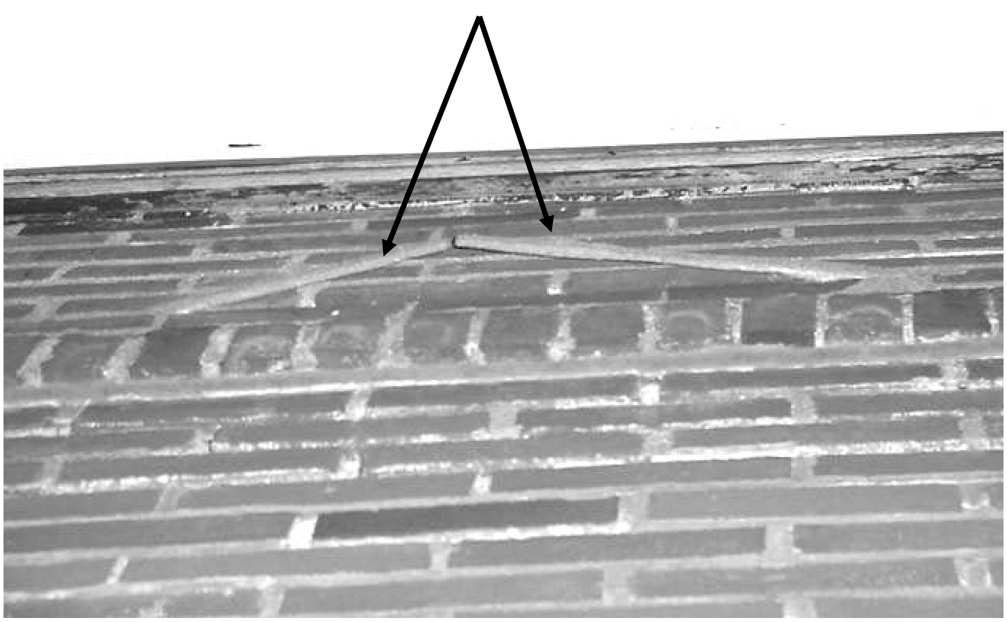
Picture 20

Bulging Exterior Wall above Board of Selectmen's Office

Picture 21

Close up of Bulging Exterior Wall above Board of Selectmen's Office
(Photo By Phyllis Brennan, Berkley Board of Assessors, 9/15/2005)

Picture 22

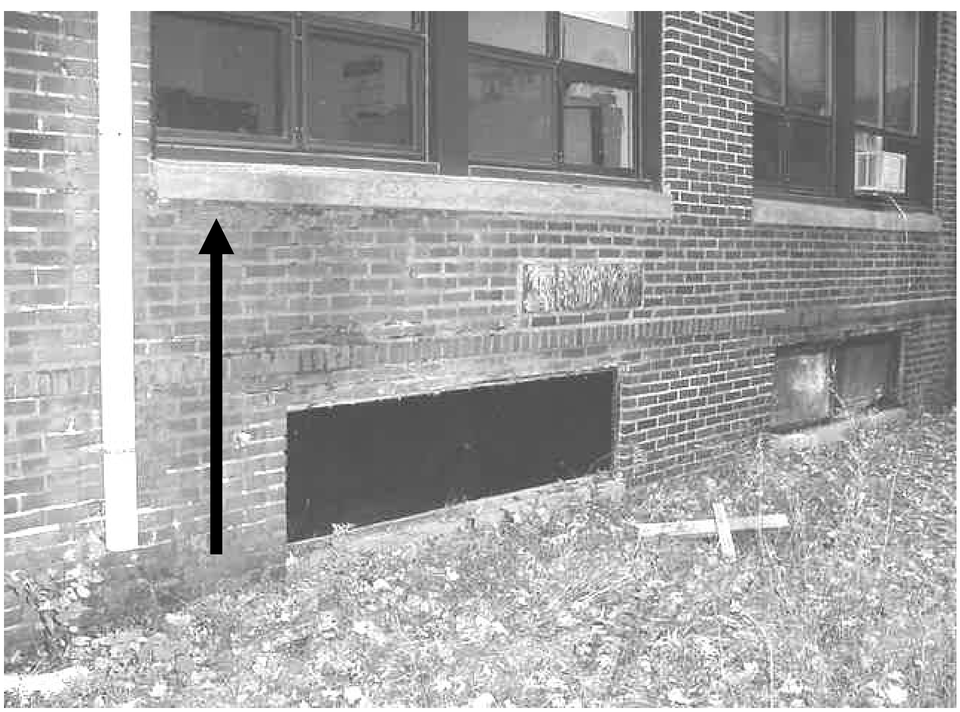


Failing Mortar, Exterior Wall

Picture 23

Spray Foam Insulation Inserted Into Mortar Joint, Front Exterior Wall

Picture 24



Spray Foam Insulation Inserted Into Mortar Joint, Rear Exterior Wall

Picture 25

Former Entrance, Rear of Building

Picture 26

Missing Roof Flashing, Northeast Corner of Building

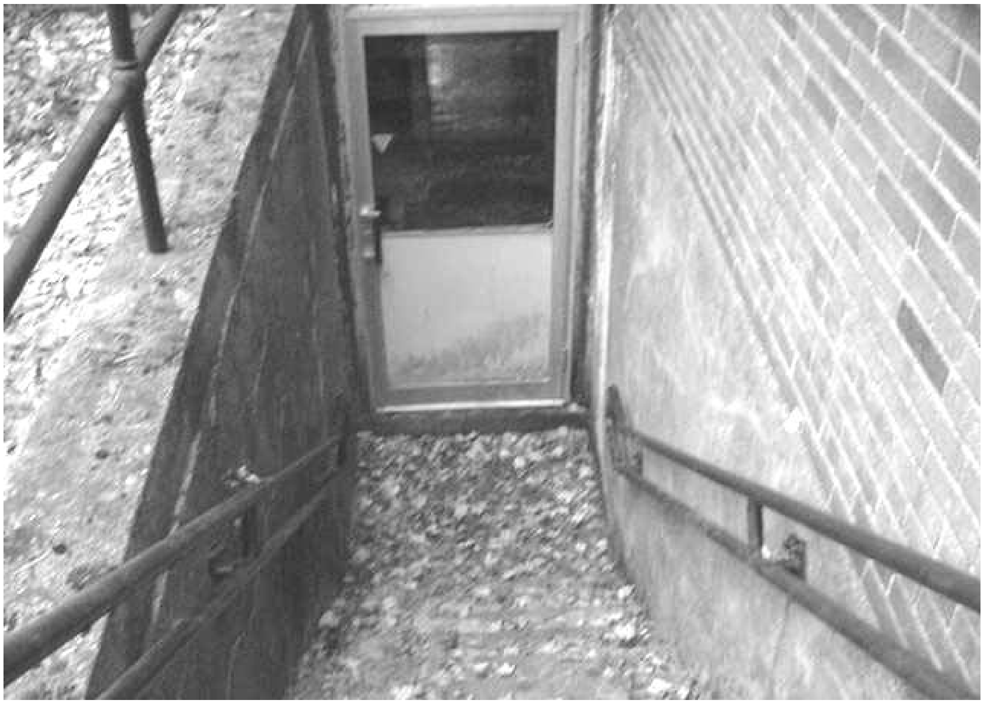
Picture 27

Moss and Water Staining In the Exterior Wall behind the Pipe Joints Indicates Clogging

Picture 28

Condensation inside Window Sash

Picture 29



Basement Entrance, Note Leaves

Figure 2 **Cross Ventilation in a Building Using Open Windows and Transoms**

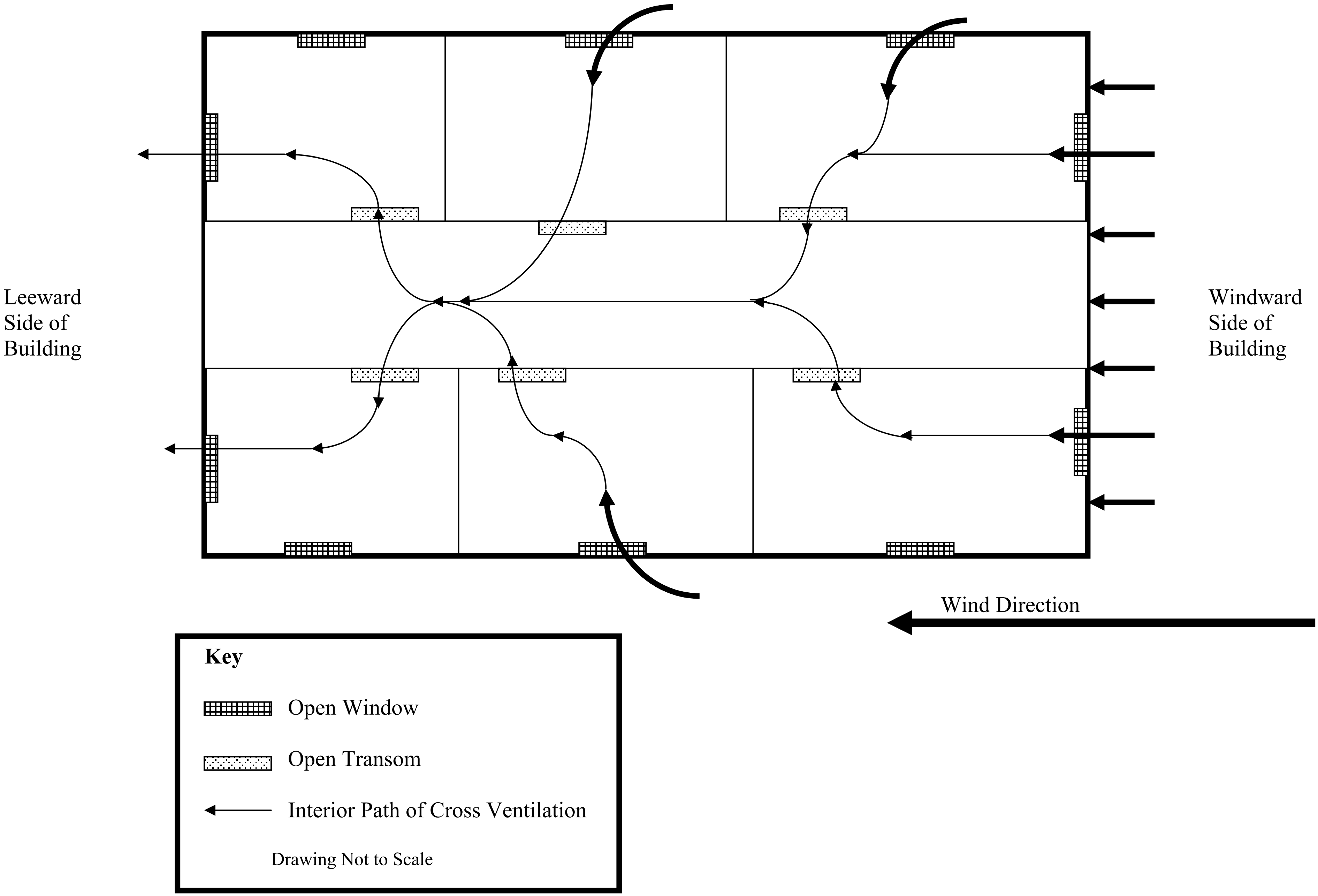


Figure 3 **Inhibition of Cross Ventilation in a Building with Several Windows and Transoms Closed**

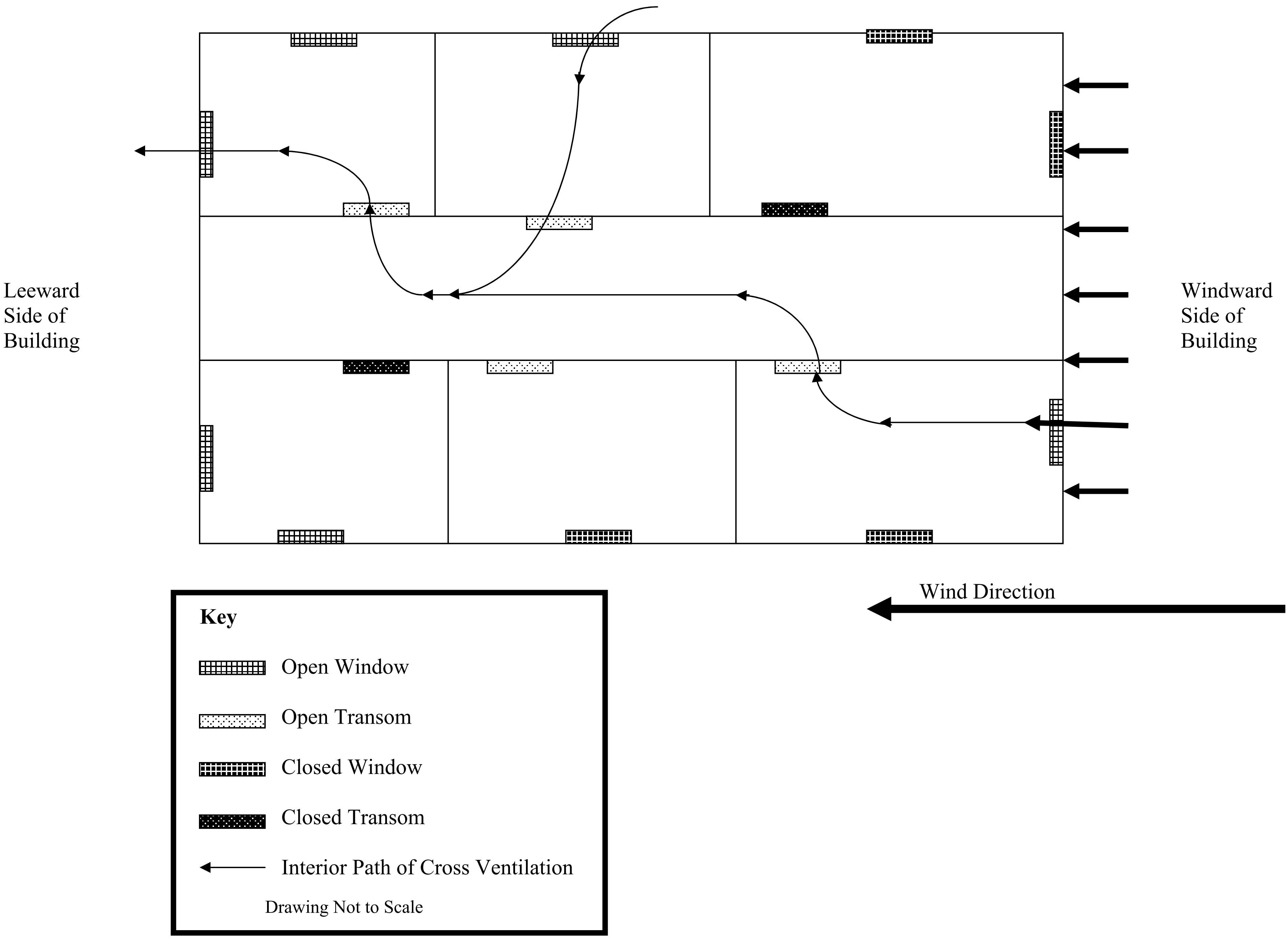


Table 1
Indoor Air Test Results
Berkley Town Offices, 1 North Main Street, Berkley, Massachusetts
November 9, 2005

Location	Carbon Dioxide (*ppm)	Temp. (°F)	Relative Humidity (%)	Occupants in Room	Windows Openable	Ventilation Supply	Ventilation Exhaust	Remarks
Outside (Background)	318	38	63					
Auditorium	413	71	44	1	Y	Y	Y	Fresh air supply off Exhaust vent off Window-mounted air conditioner Condensation in windows Door open
Board of Selectmen	555	71	43	1	Y	Y	Y	Fresh air supply off Exhaust vent off Window-mounted air conditioner Condensation in windows
3B	536	72	43	0	Y	N	Y	Exhaust vent off
5	559	75	41	0	Y	N	N	Water damaged window sill Photocopier
4	629	76	42	1	Y	Y	N	Water damaged plaster Fresh air supply off

*** ppm = parts per million parts of air**

Comfort Guidelines

Carbon Dioxide -	< 600 ppm = preferred 600 - 800 ppm = acceptable > 800 ppm = indicative of ventilation problems
Temperature -	70 - 78 °F
Relative Humidity -	40 - 60%

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						Supply	Exhaust	
2	567	72	42	1	Y	Y	Y	Wet carpet Fresh air supply off Exhaust vent off Window-mounted air conditioner Door open
1	717	73	43	3	Y	Y	Y	Wet carpet 3 water damaged ceiling tiles Water damaged window sill Fresh air supply off Exhaust vent off Window-mounted air conditioner Door open
3	719	72	39	2	Y	Y	N	Wet carpet Water damaged window sill Fresh air supply off Window-mounted air conditioner Door open

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						Supply	Exhaust	
Museum	475	69	45	0	N	Y	N	Mold contaminated materials (see report) Musty odor 3 water damaged ceiling tiles Fresh air supply off Door open
Cable TV studios	474	68	42	0	N	Y	N	Most ceiling tiles missing Fresh air supply off Door open
Room B9	580	68	52	0	N	N	N	Mold contaminated materials (see report)
Room B8	582	68	54	0	N	N	N	Mold contaminated materials (see report)

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